

Tourism LCA: state-of-the-art and perspectives

Camillo De Camillis · Andrea Raggi · Luigia Petti

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Abstract

Background, aim and scope Records over the last decades indicate a high growth rate for tourism, making it one of the most important industries in the world economy. Since estimates outline a consolidation of this trend, an accurate identification and assessment of the environmental impacts related to the life cycle of tourist products is increasingly necessary. By reviewing and comparing Life Cycle Assessment (LCA) case studies in the tourism sector, this paper aims to identify life cycle approaches that may be used as a basis for the subsequent development of sectorial Life Cycle Thinking guidelines.

Main Features The following characterising elements were analysed for each case study reviewed, bearing in mind ISO 14044:2006 contents: goal, functional unit, system boundaries, inventory data quality and assessment methods of the environmental impacts.

Results The few LCA implementations found in the literature vary considerably as regards the object studied and the methodological choices made. Specifically, the objects studied could be categorised as follows: accommodation services; buildings (hotel structures); tourist package holiday; the entire tourism industry. The main methodological choices

made regard: system boundaries, data quality requirements and methods for assessing environmental impacts.

Discussion A critical analysis of case studies revealed considerable dissimilarities as regards time reference and methodology application. Even though these differences made any comparison of results difficult, a few findings on methodological approaches might be outlined. Because the goal and scope definition profoundly affects LCA results, particular emphasis has been given to objectives and system boundaries.

Conclusions The low number of studies found in the literature could indicate either that there are significant obstacles to adopting this approach or the limited awareness of LCA in tourism's drivers. The main obstacles might be: the complicated nature of the tourism system; the lack of specific LCA databases for tourism and related sectors; the tourism industry's low consideration of the environmental impact categories that are generally taken into account in impact assessment methodologies.

Perspectives In order to promote the applicability and dissemination of LCA within the tourism sector, a number of methodological approaches and guidelines should be developed further. Moreover, it might be necessary to look into the possibility of integrating LCA with other instruments, such as environmental support tools for assessment, management, and design, as well as communication and marketing. Further synergies should be investigated regarding environmental instruments for passenger transportation, and specific tools that focus on the economic and social aspects of sustainability.

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C. De Camillis (✉)

Dipartimento di Scienze, Università degli Studi "G. d'Annunzio",
viale Pindaro, 42,
65127 Pescara, Italy
e-mail: c.decamillis@gmail.com

A. Raggi · L. Petti

Dipartimento delle Scienze Aziendali, Statistiche,
Tecnologiche ed Ambientali,
Università degli Studi "G. d'Annunzio",
viale Pindaro, 42,
65127 Pescara, Italy

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1 Background, aim and scope

Tourism as an economic activity is attracting more and more interest within the scientific community due to its ever-increasing international importance. The high growth rate that has characterised the tourism market over the last decades has, in fact, established the tourism industry as one of the principal sectors of the world economy and estimates for the coming years predict the consolidation of this trend (Raggi and Petti 2006a, b; UNWTO 2008; UNWTO, UNEP 2008).

While a greater incidence of services in the global economy may be considered as functional in the economic dematerialization required for environmentally sustainable development, the growing role of tourism requires that tourist services should be accurately assessed from an environmental viewpoint. It is commonly thought that many services have little impact, due to the limited level of direct material intensity and polluting emissions in the supply phase of these services. Nevertheless, the overall environmental impact of services may be significantly increased by the supply of inputs they require.

Through a detailed review of the international scientific literature on the environmental sustainability of the tourism sector, we identified numerous academic works on methods and tools as well as case studies. These works tackled problems linked to the evaluation of the environmental impacts of the sector from different points of view and at different depths of analysis (Peeters et al. 2007; Hunter and Shaw 2007; Weaver 2006; Gössling et al. 2005). Very few studies were based on a Life Cycle Thinking (LCT) approach, or especially on Life Cycle Assessment (LCA).

This article firstly illustrates the procedure used to review the literature and then gives a concise description of the case studies reviewed. The paper offers a comparative analysis, in order to identify potential preliminary approaches for the subsequent development of LCT guidelines for the tourism sector. Lastly, further research perspectives are outlined.

2 Main features

Searches were performed in different sources of scientific literature—scientific papers, books, reports, etc.—that dealt with LCA for tourism by accessing OPACs (On-line Public Access Catalogues), scientific research databases (e.g. ScienceDirect, Emerald, SpringerLink), sector specific databases (e.g. Leisure Tourism Database, World Tourism Organization), and web search engines (e.g. Google Scholar). In addition, the proceedings of the main conferences on LCA and on sustainable tourism were reviewed. Each case study found in the literature was then critically analysed, considering the LCA approach and the following characterising elements, bearing in mind ISO 14044:2006

contents: study object, purposes, functional unit, system boundaries, inventory data quality and assessment methods of the environmental impacts. Finally, findings on LCA purposes, product categories and related system boundaries were outlined and case studies were grouped according to the stakeholder concerned and the study object category. Input–Output LCA case studies found in the literature on the tourism sector (Patterson and McDonald 2004; Rosenblum et al. 2000; Horvath 2000) were not analysed because they were considered outside the scope of the paper.

3 Results

A limited number of LCA case studies in the tourism sector were found in the literature. The earliest application dates back to the nineties, when a British organisation, the UK Centre for Economic and Environmental Development (UK CEED) implemented two LCAs for the tour operator British Airways Holidays (BAH) to assess the environmental issues from a life cycle perspective of two of the company's major destinations, the Seychelles (Sisman 1994) and St. Lucia (UK CEED 1998). The first LCA on accommodation services was conducted in Italy at a later date and considered the services provided by a three-star hotel (Tontodonati 2002; Petti and Tontodonati 2002). The Chinese Natural Science Foundation also funded LCA studies on tourism in National Parks (Shi et al. 2003) and Chambers (2004) used this methodology to compare and analyse the differences between two package holidays in Bulgaria. A second case study on accommodation services was implemented in Italy on a four-star hotel (Mazzoni 2004; Mazzoni et al. 2004); its findings and those from the previous Italian study were reported and discussed by Raggi et al. (2005). More recently, König et al. (2007) applied a comparative LCA to the design of a hotel complex in Portugal, whilst conventional LCA was implemented in Italy for the accommodation and spa services provided by a two-star hotel (Florida 2007), and for an entire spa holiday (Corsico 2007), as reported by Castellani et al. (2008) and Sala and Castellani (2009). Lastly, LCA methodology was implemented in the accommodation services provided by another three-star hotel in Italy (De Camillis et al. 2008), and finally to the entire tourism sector of the Penghu island in Taiwan (Kuo and Chen 2009).

In order to outline an overall overview of the LCA methodologies and application approaches used, the main results of the critical analysis of these case studies are reported in Tables 1 and 2. In particular, Table 1 illustrates the LCA methodologies followed, categorised either as “conventional” or “non conventional” according to their claimed (or supposed) compliance or non-compliance with the reference LCA standards; only the methodology used by Sisman (1994) was analysed according to the relevant

Table 1 Overview of LCA case studies in the tourism industry: methodology, study object, purposes and functional unit

Reference	LCA methodology	Study object	Purposes	Functional Unit
Sisman 1994	Non-conventional	Package holiday offered by the tour operator British Airways Holidays (BAH) in the Seychelles	Identification of environmental hot spots to define improvement actions to be carried out by various stakeholders	Not clearly defined
UK CEED 1998	Non-conventional	Package holiday offered on the island of St. Lucia by the tour operator BAH	Identification of environmental hot spots to define improvement actions to be carried out by various stakeholders Environmental comparison of the all-inclusive package holiday with the basic one	Not clearly defined
Tontodonati 2002 Petti and Tontodonati 2002	Conventional	Services provided by Hotel Prestige, Montesilvano, Italy	Identification of the environmental hot spots of hotel services Gaining LCA experience to define the Product Category Rules (PCRs) for Type-III environmental labelling	Accommodation service referred to a one-night stay of one guest
Chambers 2004	Non-conventional	Two package holidays offered in Bulgaria at a seaside resort (mass tourism) and in the mountains (eco-tourism)	Comparative assessment of the environmental impacts linked to two package holidays belonging to contrasting service types: mass tourism and eco-tourism	Data were collected “per study group per package holiday”, even if the mass tourism package lasted three days less than the eco-tourism package. Data were also analysed “per passenger per night” and “per passenger per package”
Mazzoni 2004 Mazzoni et al. 2004	Conventional	Services provided by Club Hotel Dante, Cervia, Italy	Support for the implementation of an environmental management system through the identification of significant environmental aspects under normal operating conditions	Accommodation service referred to a one-night stay of one guest, including also breakfast and restaurant services
Florida 2007	Conventional	Tourist structures and services of hotel Terme Belvedere, Abano Terme, Italy	Assessment of the environmental damages generated by the hotel building along its life cycle (from the construction to the change of use, till the demolition phase); Identification of environmental hot spots to define potential improvement actions and management strategies for structures and services provided (i.e., accommodation and spa services)	Not clearly defined. According to the study authors, the following elements were taken into account: building dimension, management and disposal; number of tourist stays per year; opening period of the hotel; life span of structures
Corsico 2007	Conventional	A standard holiday in the spa destination Abano-Montegrotto Terme, Italy	Identification of the holiday phases responsible for most environmental impacts; Identification of the most significant impact categories; Definition of potential improvement actions which can be implemented by stakeholders to reduce the environmental impacts of holidays	A one-week standard spa holiday in Abano-Montegrotto Terme including transport services to reach and leave the tourist destination
König et al. 2007	Conventional	Design solutions for a hotel to be built in Portugal	Comparison of three alternative types of hotel designs to select the best one from an environmental point of view. Type A was characterised by traditional materials and building techniques, wood-fuelled heating systems, solar thermal collectors, no air-conditioning. Type B combined traditional materials with industrialised building techniques, heating and hot water from gas, photovoltaic, no air-conditioning. Type C used conventional materials and techniques, heating and hot water from fossil fuels, air-conditioning	Construction over the life cycle (80 years) including operational energy use

Table 1 (continued)

Reference	LCA methodology	Study object	Purposes	Functional Unit
De Camillis et al. 2008	Conventional	Services provided by Hotel Duca d'Aosta, Pescara, Italy	Identification of the environmental hot spots of accommodation services; Increase LCA experience to define the PCRs for Type-III environmental labelling	An overnight stay of one guest with breakfast and car-parking services included
Kuo and Chen 2009	Non-conventional	Tourism sector of Penghu island, Taiwan	Exploration of the environmental loads generated by tourism in the island	Whole trip of one tourist in Penghu island (average length of tourists' stay: 3.2 days)

LCA literature (Heijungs et al. 1992; SETAC 1993) which dated back to before the issue of the first LCA standard. In addition to the categorisation of methodology, Table 1 also presents study objects, purposes and functional units, while Table 2 shows system boundaries, data quality, and assessment methods. No information was provided on case studies mentioned by Shi et al. (2003) because so far no detailed documentation has been found or made available.

4 Discussion

A critical analysis of case studies revealed considerable dissimilarities as regards time reference and methodology application. Even though these differences made any comparison of results difficult, a few findings on methodological approaches—in particular on LCA purposes and system boundaries—might be outlined by analysing case studies according to the stakeholder concerned and the study object.

A number of LCA purposes could be defined when case studies were considered by stakeholder category and the potential of LCA in this sector was hypothesised. Thus, the main uses of LCA by specific tourist organisations and tour operators would be: to assess environmental performance for the identification of hot spots either for internal purposes or to comply with requirements of environmental standards (e.g. ISO 14001:2004, EMAS, PCRs based on ISO 14025:2006); to help to improve performance by comparing innovative environmental technologies; to compare the environmental performance of tourist products; to sustain eco-design choices and to support green marketing. Moreover, governmental organisations might use the tool: to assess the environmental performances of a tourist destination for the identification of hot spots; as an aid in the drawing-up of local marketing projects for tourism; to assess the environmental burden of each different form of tourism developed in the area; to compare mobility plans from an environmental viewpoint; to environmentally compare waste management scenarios in order to define a local management project for wastes; to assess, plan and forecast environmental impact scenarios if

integrated with Strategic Environmental Assessment (SEA), Environmental Impact Assessment (EIA) and even with Geographic Information System (GIS); to support the Green Public Procurement; to support the implementation of Environmental Management Systems, such as ISO 14001:2004 and EMAS. Finally, NGOs might use LCA to support their environmental campaigns.

As regards the study object, most studies (five) relate to hotels (Tontodonati 2002; Mazzoni 2004; Floridia 2007; König et al. 2007; De Camillis et al. 2008), four to entire holidays (Sisman 1994; UK CEED 1998; Chambers 2004; Corsico 2007) and one to the whole tourism sector (Kuo and Chen 2009).

Different system boundaries have been outlined in the literature according to the purpose of the LCA and the study object.

For hotels, the life cycle phases were defined according to the building life cycle, mainly to assess the environmental performances of the building itself and its related services (Floridia 2007), or to support an eco-design process which aimed to compare various building designs (König et al. 2007). A different approach was adopted to assess and improve the environmental performance of the hotel services alone (Tontodonati 2002; Mazzoni 2004; De Camillis et al. 2008). To this end, the building life cycle was excluded from the system boundaries, whilst the data on guest transportation and other supporting services (e.g. room cleaning, laundry) had to be taken into consideration together with data dealing with accommodation services. No particular emphasis was given to buildings in these studies because of the impossibility of reducing the burden of structures that already exist, at least as regards the construction phase. However, findings on the life-cycle-based GHGs emissions of hotel structures (Floridia 2007; Sesartic and Stucki 2007) might suggest that their environmental loads should be included not only for eco-design purposes, but also for comparison of the services of hotels that have been built using different construction techniques (e.g. cement-based against wood-based structure). Another controversial issue is the enlargement of system boundaries to include guest transportation and other tourist activities. According to Tontodonati (2002), Mazzoni (2004)

Table 2 Overview of LCA case studies in the tourism industry: system boundaries, data quality, and assessment method

Reference	Life cycle phases included in the system boundaries	Data quality	Environmental impact assessment method
Sisman, 1994	Construction of tourism infrastructures, infrastructure management, transport of goods and tourists within the Seychelles' spatial boundaries, resource use and consumption, and waste disposal	Quantitative information are very limited and deriving from interviews conducted with hotel managers	A qualitative matrix approach was used to assess environmental loads by life cycle stages and by impact category. A few local environmental issues were also considered (e.g. aesthetic impact, noise pollution, destruction of coral reefs)
UK CEED 1998	The life cycle stages considered are the same as in Sisman's study with the addition of the phase of air transportation of passengers to the destination and return	Quantitative information are very limited and deriving from literature or questionnaires	A qualitative matrix approach like that used in Sisman's study
Tontodonati 2002 Petti and Tontodonati 2002	Travel of the hotel guests from home to hotel and vice versa, and hotel services (reception and administration, lodging)	Foreground system data were collected on site, whilst data to model the guest transportation were estimated. The professional database of GaBi 4 software was mainly used to support the background system modelling	CML96
Chambers 2004	Travel of British passenger from home to the departure airport and vice versa, airport services, flights, transfers, accommodation and other tourist activities	Data were gathered through direct interviews, literature analysis or calculated	The following indicators and environmental flows were used: kg CO ₂ eq.; food consumption; solid waste production; water use; release of chemicals and waste cooking oil. Moreover, the ecological footprint analysis was used for the comparative evaluation
Mazzoni 2004 Mazzoni et al. 2004	Travel of the hotel guests from home to hotel and vice versa, and hotel services (reception and administration, lodging, catering services)	Foreground system data were collected on site, whilst estimations were used to model the guest transportation. The professional database of GaBi 4 software was mainly used to support the background system modelling	CML96
Florida 2007	Extraction of raw materials, manufacturing of building products, building construction, use and management of structures, including activities of hotel maintenance, end of life of building materials	Primary data about the usage of the hotel building for accommodation and spa services were collected directly on site. As regards the building construction phase, construction material quantities were estimated whilst the ECOINVENT database was mainly used for the background system modelling	Eco-indicator 99, EDIP 96-2003 and EPS 2000
Corsico 2007	The holiday life cycle was modelled as two main systems: passenger transportation (i.e., car, train and flight) and all the tourist activities carried out in the spa destination (i.e. accommodation, excursions, restaurant and spa services)	Primary data were collected for tourist activities (consumption phase). Moreover, ECOINVENT and further databases included in the SimaPro 7.0 software were used to model the transport phase and the background system.	Eco-indicator 99, EDIP 96-2003 and EPS 2000
König et al. 2007	Construction, maintenance, use (cleaning), restructuring, end-of-life demolition (a service life of 80 years was assumed)	The inventory was compiled by using databases contained in the LEGEP software: ECOINVENT, Baustoff Ökoinventare (Kohler and Klingele, 1995) and a specific database on construction products created by the LEGEP software house	The following indicators were used to assess the environmental impacts: Climate change (kg CO ₂ eq. /m ²), Acidification (kg SO ₂ eq. /m ²), Eutrophication (kg PO ₄ ⁻³ eq. /m ²), Non-renewable energy (MJ/m ²)
De Camillis et al. 2008	Tourist transport to the hotel, accommodation services (parking, reception and administration, lodging, and breakfast) and transport back home	Primary data were mainly collected for hotel services. A survey on the travelling modes supported the modelling of the transport phase. The professional database of GaBi 4 software was mainly used to support the background system modelling	CML2001
Kuo and Chen 2009	Transport to Penghu island (airplane, ship), transport within Penghu island (two-stroke motorcycle, four stroke motorcycle, rental car, small shuttle bus, tour bus), accommodation (hotel, B&B, camp site, private home), recreation activities (sightseeing, historic site visiting, landscape visiting, motorised water activity, swimming, nature watching, rafting, fishing)	Questionnaires were submitted to tourists to model the holiday features in Penghu island. On this basis, literature data were used to inventory the travel and tourist processes	Environmental loads were not classified and no characterization was done. Findings were obtained through the analysis of individual environmental flows

and De Camillis et al. (2008), guest transportation has to be assessed because hoteliers are directly responsible for the location of their structures and could also influence the mode of transport that guests choose (e.g. by offering discounts to guests travelling with a given means of transportation). Lastly, further tourist services (e.g. beach facilities in the case of coastal tourism) should be considered in LCAs for hotel services where direct hotelier responsibility can be verified. Thus, analyses of tourist service location and investigations into existing collaborations could be carried out.

As regards studies on holidays, a number of similarities on system boundary definition can be found in the LCA literature (Sisman 1994; UK CEED 1998; Chambers 2004; Corsico 2007), in a few ecological footprint studies (Peeters and Schouten 2005; Hunter and Shaw 2007) and in papers on GHGs emissions (Becken and Hay 2007; UNWTO, UNEP 2008; Peeters et al. 2009). In particular, Chamber's "door to door" approach (Chambers 2004), which includes process units from the departure to return of tourists, was adopted in many cases. An even broader boundary framework could be depicted if the holiday life cycle were to be considered as the overall tourist experience, which Judd (2006) identified as the actual product of the tourism industry. Such an experience is the result of a number of tourist processes which are connected to each other. In fact, generally there is a phase that precedes the tourist experience involving the acquiring of information with a booking phase either at a travel agency or on Internet, and the purchase or rent of goods (especially clothes) for the holiday. The travel phase includes all the movements carried out by tourists from their departure to their return home. At the destination, the hospitality structures receive guests for one or more nights, restaurants offer their food services and tourist activities take place. Public services and other supporting services should also be considered in this phase as part of the holiday experience. After returning home, the final phase includes all the activities that mark the return to everyday life. This general outline of the tourist experience illustrates how the wide range of services and products involved in a holiday makes its assessment very complicated.

The life cycle structure outlined by Kuo and Chen (2009) for the analysis of the entire tourism sector of Penghu Island is similar to the "door to door" approach. In fact, tourist transportation, accommodation and recreation activities were all considered in this case. Even though Kuo and Chen (2009) recognised the need for further investigation into hidden environmental loads to make their LCA on the tourism sector more comprehensive, preliminary information on the missing process units could be found by analysing IO LCA findings (Patterson and McDonald 2004; Rosenblum et al. 2000).

5 Conclusions

The low number of studies found in the literature could indicate either significant obstacles to the adoption of LCA or limited awareness of this methodology by tourism drivers. Obstacles may include: the complicated nature of the tourism system; a lack of specific LCA databases for tourism and related sectors; the low consideration the tourism industry has of the environmental impact categories generally considered in impact assessment methodologies.

In an initial attempt to make tourism analysis less complicated from an LCA perspective, a few product categories were identified (i.e. hotel services and package holiday), and preliminary LCA approaches for this sector were indicated. In particular, special emphasis was given to system boundary definition. The "modular" LCA approach might be applied to aid in the analysis of LCA results and make their comparison easier. This approach, developed by Petti et al. (2004) for hotels, individually assesses each service (module) supplied by the tourist structure. Thus, the environmental impacts within the product system can be calculated by totalling the impact of all the services (modules) considered in such a study (e.g. catering, sauna, pool, etc.). A simplified LCA approach could be used to facilitate implementations in all three study purposes analysed.

Secondly, the large number and variety of products and services involved in tourist activities could make their Life Cycle Inventory difficult. In fact, this sector shares the problem of LCA data availability and quality with numerous other industries. Therefore, specific LCA databases for tourism and related sectors would be helpful in ensuring the completeness of LCA results and would drastically reduce the implementation time. Careful consideration is needed to decide whether it is necessary to compile an ad hoc database or whether existing ones could at least partially cover most of the applications in the tourism sector. On the other hand, the strong link between tourist services and the specific characteristics of a territory means that careful evaluation should be made of the need to use regionalised data. A hybrid LCA approach might be used as an alternative to database development. However, whilst this solution seems to be the easiest from an LCA analyst's viewpoint, Input–Output table data quality does not appear adequate for the assessment of tourist activities due to the high level of aggregation within each sector. Such an approach might be better justified in the case of sector analysis alone.

Finally, the limited focus on local environmental issues by current LCIA methods might have negatively affected the diffusion of LCA in the tourism sector. In fact, tourists seem to be particularly sensitive to local environmental issues, such as noise pollution, hydro-geological disruption,

and smell pollution, and the lack of these impact categories in LCA could have meant that alternative environmental instruments were chosen. A possible solution would be the use of non-conventional methodological approaches (e.g. GIS applications), which emphasise a proper distribution of impacts over time and space, to back up LCA studies.

6 Perspectives

Several methodological challenges have emerged from the literature on tourism LCA, as well as a number of opportunities that could be exploited. Further development of methodological approaches and guidelines is therefore required, preferably in line with the International Reference Life Cycle Data System (ILCD) Handbook (European Commission 2009), to encourage the application and dissemination of LCA within the tourism sector (Raggi and Petti 2006b; Raggi et al. 2008a, b).

Moreover, it might be necessary to look into the possibility of integrating LCA with tourism-related instruments, such as environmental support tools for assessment, management and design as well as in communication and marketing (e.g. various forms of eco-labelling).

Among the environmental assessment tools, TourBench (Van Der Burghs 2003), a free online European monitoring and benchmarking instrument to reduce environmental consumption and cost in tourist accommodations, could be improved by broadening its scope to other tourist services and covering their entire life cycles in compliance with EPD rules. In this way, tourist services could easily obtain EPDs, thus reducing costs for consultancy.

As far as environmental management standards are concerned, in addition to the well-known ISO 14001:2004 and EMAS, LCA principles could be addressed to Travelife (Kusters 2004), a sustainability management system specifically developed for tour operators. This management system, which has already become relatively widespread, could be further improved by integrating LCA findings into the environmental criteria used for the qualification of tour operator suppliers.

Findings from LCA case studies could be useful in setting up tourism-specific eco-design instruments (De Camillis et al. 2010). According to Raggi and Petti (2006a), for instance, environmental hot spots of tourist services could be integrated into the matrices of QFD, a quality management and design methodology originally developed to transfer the concepts of quality control from the manufacturing process into product design and the development process (Akao 1990).

Moreover, LCA findings could be used to improve the criteria of the wide variety of eco-labels in the tourism sector (e.g. Viabono, Legambiente Turismo, The Green

Key, Milieubarometer, Ibex-label). Finally, these eco-labels could be ranked in terms of environmental effectiveness by comparing their schemes on the basis of LCA and thus providing tourists with better information.

Further synergies might be investigated regarding environmental instruments for passenger transportation. For instance, EcoPassenger (Knörr 2008), a user-friendly internet tool for the comparison of passenger transport modes in Europe from a life cycle perspective, could be used to support eco-friendly planning of holidays. Lastly, attention might be drawn to other sustainability pillars in addition to environmental issues in order to investigate the sustainability of tourism in a more comprehensive manner (Watson et al. 2009).

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References

- Akao Y (1990) Quality function deployment: integrating customer requirements into product design. Productivity, Cambridge
- Becken S, Hay JE (2007) Tourism and climate change: risks and opportunities. Channel View, Clevedon
- Castellani V, Piccinelli E, Sala S (2008) LCA ed Impronta Ecologica a supporto della pianificazione territoriale in località turistiche, Proc. "Ecomondo 2008", Rimini, Italy, 5–8 November 2008, pp 491–495
- Chambers T (2004) Environmental assessment of a mass tourism package holiday and a responsible tourism package holiday, using life cycle assessment and ecological footprint analysis. Master degree thesis, University of East Anglia, Norwich, UK
- Corsico S (2007) Adattamento della metodologia LCA all'analisi e valutazione degli impatti generati dal turismo: un caso di studio. Final degree dissertation (in Italian), prof D Pitea (supervisor), Università degli Studi Milano-Bicocca, Milan, Italy
- De Camillis C, Petti L, Raggi A (2008) LCA: a key-tool for sustainable tourism? Proceedings of the 8th international conference on EcoBalance, Tokyo, Japan, 10–12 December 2008, pp 485–488
- De Camillis C, Raggi A, Petti L (2010) Ecodesign for services: an innovative comprehensive method. International Journal of Sustainable Economy (in press)
- Commission E (2009) International Reference Life Cycle Data System (ILCD) Handbook (draft version). European Commission, Joint Research Centre (JRC), Institute for Environment and Sustainability (IES), Ispra
- Florida D (2007) Studio delle metodologie di Life Cycle Assessment applicate al servizio turistico: il caso di una struttura ricettiva di Abano, Montegrotto. Final degree dissertation (in Italian), prof. D Pitea (supervisor), Università degli Studi Milano-Bicocca, Milan, Italy
- Gössling S, Peeters P, Ceron JP, Dubois G, Patterson T, Richardson RB (2005) The eco-efficiency of tourism. Ecol Econ 54(4):417–434
- Heijungs R, Guinée JB, Huppes G, Lankreijer RM, Udo de Haes HA, Wegener Sleeswijk A, Ansems AMM, Eggels AMM, van Duin R, de Goede HP (1992) Environmental life-cycle assessment of products: guide and backgrounds. Centre for Environmental Science, Leiden

- Horvath A (2000) LCA in the service industries: case study of telecommunications and tourism. Proc. of the international conference and exhibition on life cycle assessment: tools for sustainability. University of California, Berkeley, 25–27 April 2000
- Hunter C, Shaw J (2007) The ecological footprint as a key indicator of sustainable tourism. *Tour Manage* 28(1):46–57
- Judd DR (2006) Commentary: tracing the commodity chain of global tourism. *Tour Geogr* 8(4):323–336
- Knörr W (2008) EcoPassenger: environmental methodology and data. Ifeu - Institut für Energie- und Umweltforschung Heidelberg GmbH, Heidelberg
- Kohler N, Klingele M (1995) Baustoffdaten—Ökoinventare. Institut für Industrielle Bauproduktion der Universität Karlsruhe (TU), Lehrstuhl Bauklimatik und Bauökologie (ifib) an der Hochschule für Architektur und Bauwesen (HAB) Weimar, Institut für Energietechnik (ESU) an der Eidgenössischen Technischen Hochschule (ETH) Zürich, M. Holliger Energie Bern. Karlsruhe, Weimar, Zurich
- König H, Schmidberger E, De Cristofaro L (2007) Life cycle assessment of a tourism resort with renewable materials and traditional construction techniques. In: Bragança L, Pinheiro MD, Jalali S, Mateus R, Amoêda R, Guedes MC (eds) Portugal SB07, Sustainable construction, materials and practices. IOS Press, Amsterdam
- Kuo NW, Chen PH (2009) Quantifying energy use, carbon dioxide emission, and other environmental loads from island tourism based on a life cycle assessment approach. *J Clean Prod* 17 (15):1324–1330
- Kusters N (2004) Demonstrating how an integrated ecolabeling and tour operating supply chain management strategy can foster sustainability in tourism. Project no. LIFE04 ENV/NL/000661
- Mazzoni E (2004) Analisi del ciclo di vita nel settore turistico: criteri per l'attribuzione dell'Ecolabel. Final degree dissertation (in Italian), prof. L. Bruzzi (supervisor), Università di Bologna, Ravenna, Italy
- Mazzoni E, Bruzzi L, Sára B, Scimia E (2004) Valutazione energetico ambientale del ciclo di vita del servizio turistico ricettivo. In: Morselli L. (Ed.) Ecomondo 2004. Atti dei seminari (in Italian), 3–6 November 2004, Rimini. Maggioli Editore, Santarcangelo di Romagna, Italy
- Patterson M, McDonald G (2004) How clean and green is New Zealand tourism? Lifecycle and future environmental impacts. Manaaki Whenua Press, Landcare Research, Lincoln
- Peeters P, Schouten F (2005) Reducing the ecological footprint of inbound tourism and transport to Amsterdam. *J Sustain Tour* 14 (2):157–171
- Peeters P, Szimba E, Duijnsveld M (2007) Major environmental impacts of European tourist transport. *J Transp Geogr* 15:83–93
- Peeters P, Gössling S, Lane B (2009) Moving towards low-carbon tourism: new opportunities for destinations and tour operators. In: Gössling S, Hall CM, Weaver DB (eds) Tourism futures: perspectives on systems, restructuring and innovations. Routledge, New York, USA
- Petti L, Tontodonati S (2002) The use of LCA as a tool to implement EPDs: an application to hotel services. Proceedings of the fifth international conference on Ecobalance, 6–8 November 2002, Tsukuba, Japan, pp 329–332
- Petti L, Raggi A, Scimia E, Sára B (2004) Eco-labelling for hotel services. Proc. of the sixth international conference on Ecobalance, Tsukuba, Japan, 25–27 October, pp 621–622
- Raggi A, Petti L (2006a) A newly developed integrated environmental-quality approach for the design of hotel services. Progress in Industrial Ecology. *An International Journal* 3(3):251–271
- Raggi A, Petti L (2006b) Life Cycle Assessment and tourism services. Oral presentation at the workshop 'Stato dell'arte e prospettive degli studi di LCA in Italia', 18 October 2006, Bologna, Italy
- Raggi A, Sára B, Petti L (2005) Life Cycle Assessment case studies in small and medium sized enterprises offering tourist accommodation services. Proc. of the 12th SETAC Europe LCA Case Studies Symposium, 10–11 January 2005, Bologna, Italy. SETAC Europe, Brussels, pp 171–174
- Raggi A, Petti L, De Camillis C., Bordin A, Boatto T (2008a) LCA dei prodotti turistici: stato dell'arte e prospettive. Proc. 2nd Workshop Italian LCA Network 'Sviluppi dell'LCA in Italia: percorsi a confronto', Pescara, Italy, 13 March 2008, pp 63–76
- Raggi A, Bruzzi L, Bordin A (2008b) The Italian LCA Network: objectives and activities of the Working Group on Tourist Services. Proceedings of the 8th international conference on EcoBalance, 10–12 December 2008, Tokyo, Japan, pp 489–492
- Rosenblum J, Horvat A, Hendrickson C (2000) Environmental implications of service industries. *Environ Sci Technol* 34 (22):4669–4676
- Sala S, Castellani V (2009) A proposal for integration between Life Cycle Assessment and other instruments and indicators as a way to promote Sustainable Production and Consumption strategies. Proc. of the 15th SETAC LCA Case Studies Symposium, 22–23 January 2009, Paris, France
- Sesartic A, Stucki M (2007) How climate efficient is tourism in Switzerland? An assessment of tourism's carbon dioxide emissions in relation to its added value. Diploma thesis, prof D Imboden and S Perch-Nielsen (supervisors), ETH, Zurich, Switzerland
- SETAC (1993) Guidelines for Life Cycle Assessment: a code of practice. Proc. of the SETAC workshop, 31 March–3 April 1993, Sesimbra, Portugal. SETAC Press, Pensacola
- Shi H, Moriguchi Y, Yang J (2003) Industrial ecology in China, Part 1. *Journal of Industrial Ecology* 6(3–4):7–11
- Sisman K (1994) A life-cycle analysis of a holiday destination: Seychelles. British Airways environment report, vol. 41. UK CEED, Cambridge
- Tontodonati S (2002) Requisiti specifici di prodotto dei servizi alberghieri. Final degree dissertation (in Italian), prof L Petti (supervisor), Università degli Studi "G. d'Annunzio", Pescara, Italy
- UK CEED (1998) An assessment of the environmental impacts of tourism in St. Lucia. British Airways Environment Report vol. 5, Cambridge, UK
- UNWTO (2008) Tourism highlights 2008 edition. UNWTO Publications, Madrid
- UNWTO, UNEP (2008) Climate change and tourism—responding to global challenges. UNWTO Publications, Madrid
- Van Der Burghs R (2003) European monitor and benchmarking initiative for environmental impacts and costs in tourist accommodation. Project no. LIFE03 ENV/NL/000473
- Watson J, Sastre F, Raya JM, Ayuso S, Fullana-i-Palmer P (2009) Sustainability impact assessment of a tourist visiting Majorca using LCA, LCC and Social LCA. Proc. of the 4th Int. Conference on Life Cycle Management, 6–9 September 2009, Cape Town, South Africa
- Weaver DB (2006) Sustainable tourism: theory and practice. Butterworth-Heinemann, Oxford